



On the Design of Intelligent Physiotherapy Bed Based on Ergonomics

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Abstract. The main goal of this study is to summarize the product design direction that is in line with human behavioral habits based on the behavioral needs of elderly paralyzed patients and combined with ergonomics principles, and to design an intelligent physiotherapy bed product that is more in line with the needs of elderly paralyzed patients. The study first systematically sorted out the domestic and foreign needs related to physical therapy beds for paralyzed patients through topic screening. Based on these needs and pain points, combined with ergonomics, an innovative physical therapy bed design plan was proposed. The program aims to create a more convenient and comfortable rehabilitation environment. This research not only provides new ideas and methods for the design of physical therapy beds for paralyzed patients, but is also expected to bring substantial improvements to their quality of life.

Keywords: Ergonomics; elderly paralyzed patients; intelligent physiotherapy bed; optimized design.

1 Introduction

With the aging population and increasing cases of paralysis among the elderly, there is a growing demand for medical equipment that can assist in the rehabilitation and care of these patients. One such device, the physiotherapy bed, is essential in supporting the physical recovery of paralyzed patients by providing comfort and aiding in rehabilitation efforts. However, current physiotherapy beds often fail to meet the diverse needs of elderly paralyzed patients, particularly in terms of ergonomic design, functionality, and caregiver support.

This study aims to design an intelligent physiotherapy bed based on ergonomic principles to address these shortcomings. The proposed design will prioritize patient comfort, ease of use, and convenience for caregivers while integrating advanced features such as posture adjustment, therapeutic support, and health data monitoring. By considering the specific needs of elderly paralyzed patients and incorporating user feedback, the design seeks to improve both patient outcomes and caregiving efficiency.

This paper will analyze the design requirements and propose solutions for creating a physiotherapy bed that optimally balances user comfort, functionality, and ease of care, contributing to the overall well-being of elderly patients and their caregivers.

2 Theory and Research Process of Physiotherapy Bed Design

A physiotherapy bed is a product used to assist users in meeting their daily needs. Its design not only needs to consider the user's behavioral habits, comfort and actual needs, but also needs to consider reducing the daily care workload of caregivers. From the perspective of engineering, especially ergonomics and user review analysis, a physiotherapy bed is a human-computer interaction device that provides users with better comfort and use effects. A physiotherapy bed system designed based on ergonomics should be able to ensure the safety, health and comfort of its users. [1]Therefore, two major factors must be fully considered in the development and design of intelligent physiotherapy beds: one is ergonomics, especially the movement characteristics and functions of the back, neck and lower limbs; the second is the human-computer physical interaction operation function, which ensures the correct coordination between the physiotherapy bed system and the human body and provides a comfortable human-computer interaction method. And these design directions can be directly extracted through user comments [2].

In order to better understand the user's evaluation and demand for smart therapy beds, the data collection work is mainly focused on the user evaluation of smart therapy beds on online sales platforms such as Taobao, Tmall and JD.com. By searching the sales status of related products on these platforms, we can understand the market sales and trends of smart therapy beds. At the same time, we deeply investigate the needs of the public, extreme situations and user preferences to better understand the needs and pain points of users (see Fig. 1).



Fig. 1. Emotional word cloud of users' needs for physiotherapy beds

After that, we summarized the words with user improvement tendencies in the comments, such as "hard", "troublesome to install", "average quality", "bed pan" and many other keywords. The information contained in these words is comprehensive enough and focuses on the functional points that users need to improve for smart therapy bed

products. Some complex emotion-oriented words, such as double negative words, need to be corrected in the emotional direction to ensure the accuracy of the analyzed emotional analysis results and keywords. In order to find out the semantic relationship contained in the text and analyze the user's familiarity with a certain function of the product, it is necessary to further refine the text and dig out the product information that users are most concerned about.

In user reviews, we found that user needs include simplified care process, convenient cleaning, comfort, comprehensive functions, and moderate price. In order to meet user needs, we need to improve the design of the smart physiotherapy bed to achieve the core purpose of the product. For example, in terms of product operation, it is necessary to design simple and easy-to-use operation links so that caregivers can operate easily; in terms of mattresses, it is necessary to design soft and comfortable mattresses to reduce the pain and discomfort of patients; in terms of cleaning, it is necessary to design easy-to-clean mattresses and bedside tables to facilitate cleaning and hygiene. Based on this, the design of the smart physiotherapy bed needs to start from the user's perspective and comprehensively consider many factors. Only in this way can we design physiotherapy bed products that meet the needs of different users, thereby achieving the core purpose of the product.

According to the direction obtained from the above review analysis, the design can be determined in the product's bed partition design, material direction, and physiological needs direction.

Closely related to the bed partition design direction is the human body's turning size. The turning size mainly depends on the data values of the human body's maximum shoulder width, shoulder width, chest width, and hip width. At present, there is no complete standard for the body size of elderly paralyzed patients in China. Due to long-term bed rest, the patients will more or less suffer from muscle atrophy, and their body size will not exceed the body size of people over 60 years old. Therefore, the design is mainly based on the standard of "Chinese Adult Body Size" (GB 10000-2023) for auxiliary design. For details. (see Figure 2)

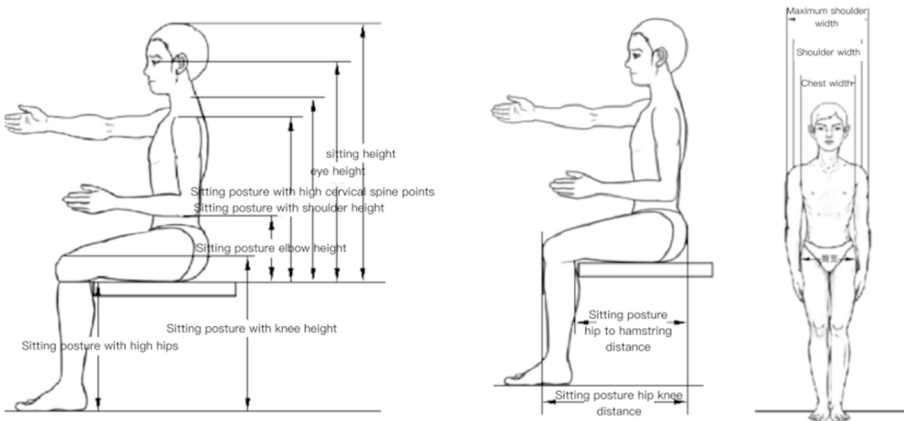


Fig. 2. Schematic diagram of the dimensions of various human behaviors.

3 Design Concept Based on Ergonomics

In view of the above-mentioned problems and related data, the design of the physiotherapy bed for elderly paralyzed patients should have the following characteristics from the perspective of ergonomics:

3.1 Turning Over and Sitting Up Assistance Function

On the basis of relevant treatment work for paralyzed patients, it is crucial to carry out predictive related nursing work. This can help patients reduce the possibility of concomitant diseases such as bedsores (pressure injuries) and aspiration pneumonia caused by excessive local pressure due to long-term bed rest.

Research results show that in order to prevent local skin from causing poor blood flow due to compression problems, thereby causing skin ulcers and bedsores, paralyzed patients need to turn over every two hours[3]. Therefore, the function of the physiotherapy bed needs to add a function point to help patients turn over. This function can be used with the help of the mechanical system of the physiotherapy bed, through the setting of the control center, to automatically turn over according to the set time and angle, so as to meet the needs of patients. From the above data, it can be concluded that due to the body shape differences of elderly patients, the size and function of the product need to be adjusted in the design. For example, according to the median body data, the shoulder width of men and women differs by 26mm, and the hip width differs by 10mm. The body size of different patients should be taken into consideration when designing to accommodate most users. The product uses a three-section design. Combined with the comfort requirements, the mattress is divided into three sections horizontally and vertically. The horizontal width is 250mm on both sides and 300mm in the middle. In the longitudinal survey, it can be concluded that the median difference in the sitting popliteal height of elderly paralyzed patients is 32mm, and the median difference in the sitting height is 51mm. Therefore, the mattress is divided into three sections: upper, middle and lower, which are 700mm, 500mm and 600mm respectively. Such a design can cover the needs of most users.

When the patient needs to sit up, lie down, raise his legs and other daily behaviors, the control center can control the physiotherapy bed accordingly according to the set angle and time. The adjustable parts on both sides can rotate to the opposite side in the form of central axis rotation, and the rotation center is the connection between the adjustable parts on both sides and the middle fixed part. This design can help paralyzed patients easily complete the turning action, and can effectively alleviate the problem of excessive local pressure caused by long-term bed rest, thereby preventing the occurrence of complications such as bedsores and aspiration pneumonia[4].

In order to facilitate the use of patients and the care of nursing staff, the upper and lower adjustable parts are set to rotate counterclockwise in sections (right viewing direction) with the middle fixed part and the connection between the upper and lower adjustable parts as the rotation axis. This segmented rotation design can meet the behavioral needs of paralyzed patients and reduce the possibility of patients suffering from osteoporosis, venous thrombosis and thrombophlebitis.

In addition, the guardrail of the intelligent physiotherapy bed can reduce the difficulty of paralyzed patients getting on and off the bed and the difficulty of nursing staff through the form of damping lifting. The design of the intelligent physiotherapy bed needs to fully consider the needs of the patient and the difficulty of the caregiver[5]. The "three-stage" structural design and segmented rotation design can better meet the needs of the patient, reduce the occurrence of complications, and improve the patient's quality of life. The damping lifting guardrail design can facilitate patients to get on and off the bed, and prevent patients from falling off the bed after rolling over (see Fig. 3). Compared with traditional physiotherapy beds, this "three-stage" structural design is more flexible and humane[6]. It can be adjusted according to the needs of different patients to meet the care needs of different patients in different postures. At the same time, the left-side rotation and right-side rotation design can also allow patients to easily complete the turning action, reduce the workload of caregivers, and improve the efficiency and quality of care[7]. This "three-stage" structural design physiotherapy bed can provide more comprehensive, flexible and personalized nursing support for paralyzed patients, helping them to relieve compression problems faster, reduce complications, and improve the quality of life.

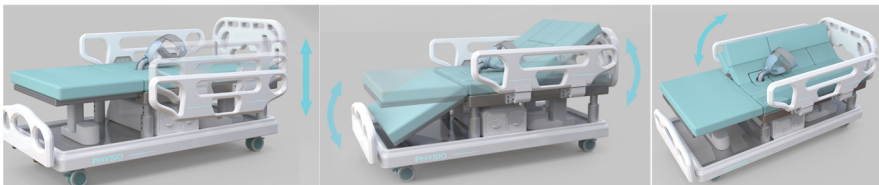


Fig. 3. The three-section structure of the left and right sides of the physiotherapy bed is displayed

3.2 Simplify Bowel Movements

The traditional way of helping paralyzed patients to defecate has brought a considerable workload to the nursing staff, and the privacy protection of the patients is not enough, which can easily lead to urinary tract infection and constipation in the patients[8]. Therefore, simplifying defecation is one of the main considerations in the design of physiotherapy beds. Therefore, the design of physiotherapy beds needs to simplify defecation and improve the privacy protection of patients. In the design process of physiotherapy beds, a wearable smart defecation device is incorporated. This innovative design mainly consists of multiple components such as cotton waist elastic band, rubber crotch, fan, water pump, heater, central control and display device. By using this device, patients can easily wear toilet cleaners and defecate on the bed. During defecation, the waste will be naturally discharged into the collection box through the sewage pipe, which is convenient and hygienic. The central control device can control the heating temperature, thereby heating the water temperature to make the defecation process more comfortable. At the same time, the fan can dry the perineum and keep the private parts clean and hygienic.

It is worth mentioning that the defecation device can run synchronously with the mechanical device of the physiotherapy bed, thus providing patients with a more comfortable defecation experience. In addition, the device can also reduce the possibility of constipation in patients, making patients more relaxed and comfortable during defecation[9]. After use, the subsequent cleaning and water change of the toilet cleaner are also relatively simple. The display can display information such as the amount of water and the degree of collection in the collection box. When a certain standard is reached, it will remind the nursing staff to pull out the collection box and water tank for dumping and cleaning. This design not only facilitates the work of nursing staff, but also better protects the privacy of patients and reduces the workload of caregivers[10].

The design of a physiotherapy bed with a wearable smart defecation device not only provides patients with a more comfortable and convenient defecation experience, but also protects the privacy of patients and reduces the workload of caregivers to a certain extent. It has high practicality and application value (see Fig. 4).

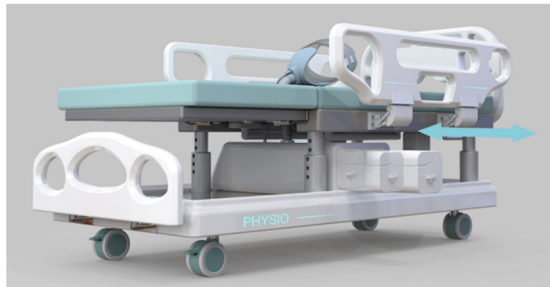


Fig. 4. The pull-out structure of the toilet of the physiotherapy bed

4 Conclusion

In product design, it is noted that there are few physical therapy facilities for elderly paralyzed patients, which even creates a psychological burden on this consumer group. With the advancement of technology, the number of elderly paralyzed patients is also increasing, and their social needs are also increasing accordingly. Designers need to pay attention not only to the needs of the mainstream young consumer groups in the market, but also to the needs of elderly users, and customize products that are more suitable for the relevant groups for their physical conditions. Therefore, designers cannot only improve related products from the appearance, but also go deep into the pain points, consider the real needs of elderly patients from the perspective of ergonomics, and achieve the basic principle of "people-oriented" industrial design.

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